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STUDY THE EFFECT OF REINFORCING FIBER TYPES ON CREEP BEHAVIOR OF PROSTHETIC SOCKET

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ABSTRACT

Due to the difficult conditions in Iraq and the increasing frequency of terrorist attacks, the number of amputees has skyrocketed. However, trans-tibial amputations account for about 80% of all amputations. The creep behavior of composites was investigated using tensile creep testing. In this investigation, fifteen laminated composites were used. The polyester polymer was used as the matrix and strengthened with fibers, including jute, glass, hemp, carbon, and person, which were created by the vacuum molding process. Socket materials were evaluated for their mechanical properties to select a laminated composite that must support loads for prolonged periods. According to the data, the best-laminated samples contained two layers of carbon fiber and three layers of natural fiber. This indicates that the hemp-carbon hybrid with a 0.00031(%/hr.) creep rate is more resistant to creep than natural fiber alone or other hybrids. As the total of fiber layers rises, the creep rate lowers. This investigation concluded that the mechanical assets were affected by the kind and quantity of supporting layers. These results highlight the natural fiber laminate's potential for orthopedic applications with improved biocompatibility.

Keywords: Prosthesis Socket; Hemp; Jute; Creep, Monofilament.

INTRODUCTION

People who have had limbs amputated frequently use prosthetics, usually referred to as artificial limbs, to regain their lost duties and form. The number and quality of lower limbs are in greater demand on the market. Because it serves as a connection between the prosthesis and the limbs, the prosthesis socket is one of the most crucial elements in deciding the type of fit [Faheed, Oleiwi, and Hamad 2022, Hamad, Rahman And Faheed 2023].

As shown in Figure 1 [Oleiwi, Hamad, and Faheed 2023], below-knee prostheses usually consist of four main parts: the shoe, pylon, foot, and connection. A socket is normally utilized as a coupler between the prosthesis and the remaining limb, covering the residual limb and housing the prosthesis' remaining constituents. Because it is the only way of transferring load between the prosthesis and the remaining limb, the socket is a critical

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constituent of an effective prosthesis [Silver-thorn M.B. 1996].

As an outcome, the prosthesis must be lightweight, pleasant to wear, durable, visually agreeable, mechanically adequate, and need minimal care. The type of replacement limb determines both the level of amputation or damage and the position of the absent limb [Khudhair A. M 2012].

Since the 1950s to the present day, the type of socket substance has evolved significantly, transitioning from leather, wood, and aluminum to plastic. Plastic kinds have evolved, beginning with thermoplastic and progressing to thermosetting. A great variety of strengthening and composites can be utilized in thermosetting. Composites such as nylon-glass, fiberglass, polyester, and carbon fiber are becoming increasingly popular around the world [Rosalam Che Me and Rahinah 2012, Issa, Faheed and Hamad 2024].

Chemicals are used to make synthetic fibers, including ceramic, aramid, glass, and carbon fibers. The custom of advanced materials based on natural fibers has amplified intensely in recent years, due to enlarged awareness and their great performance at reasonable rates [Widhata, Ismail, and Sulardjaka 2019].

Natural fibers are a substitute source for man-made fibers for example glass, and carbon fibers as strengthening for polymer in producing renewable, inexpensive, and environmentally friendly composites owing to their particular qualities, health benefits, and recyclability [Sathishkumar, Naveen, and Satheeshkumar 2014]. Jute, hemp, and monofilament fibers are viewed as the most viable reinforcements for polymeric composites because of numerous benefits, including increasing accessibility, low manufacturing costs, and acceptable mechanical qualities when associated with other fibers [Bharath and Basavarajappa 2016].

The adjoining matrix preserves the hybrid fibers in the anticipated position and orientation, serving as a higher load transfer moderate between them. Hybrid fibers, composed of a natural/synthetic blend or a mix of natural and artificial fibers, can endure higher loads in dissimilar directions than single-fiber reinforcements [Yadav R. K. (2013)].

The surrounding temperature influences the prosthetic socket's mechanical properties, which is partially caused by internal stresses resulting from the different thermal coefficients of the composite constituents (reinforcement and matrix). The degree of this interior stress varies with temperature, and in certain situations, the matrix will crack at extremely low temperatures. Continuous exposure to high-stress levels under the material's yield strength causes creep, which always rises with temperature. The pace of this deformation depends on the material's characteristics, exposure duration, exposure temperature, and imposed structural load. The maximum use temperature of a polymer is often just below its glass transition temperature (Tg), which is the point at which the polymer transitions from a hard to a rubbery form and significantly loses its mechanical capabilities [Faheed, Issa, And Hamad 2024].

The locked surroundings of the remaining limb and socket produce warm and humid environments, which may lead to an increase in residual limb skin issues that may cause blistering, skin irascibility, and condensed value of life. This is why lower-limb amputees discover their sockets uncomfortable. The socket, suspension structure, and liner's design, manufacture, and material choice [Faheed, Hamad, and Oleiwi 2022) may lessen these problems.

The researchers studied in this field, [Ismail, Jweeg, and Resan 2013)], the effect of temperature on a composite materials socket during walking was investigated in nations with hot climates. They found that creep causes the socket's mechanical qualities to decrease over time as the temperature rises and that the combination of creep and fatigue causes socket failure. [Ali, Kumar, and Singh 2014], Transtibial prosthetic sockets were created via the vacuum molding method, with epoxy resin serving as the bonding agent and Perlon, carbon, glass, and (carbon and glass) with silica components utilized as reinforcement. [Lee, Lythgo, Laing, Lavranosand Thanh 2014], Trans tibial (TT) prosthetic sockets were made and fitted in a poor nation using the pressure casting process, which was inexpensive and required little expertise [18]. [Chiad J.S. 2014] To choose the best-laminated socket for the below-knee prosthetic socket, a variety of laminated options were created, grouped as follows: (4 perlon with 2 carbon with 4 perlon), (3 perlon with 2 carbon with 3 perlon), and (3 perlon with 1 carbon with 3 perlon). Because it lowers the weight and expense of the prosthetic socket, the outcomes show that the unsurpassed lamination is made up of three perlon plus carbon fiber plus three perlon. [Al-razaq Resan, and Ibrahim 2016], in this work, a novel modular socket system (MSS) that employed direct lamination on patients' remaining limbs was used to fabricate a new type of socket. Socket materials were put through tensile and creep testing at 50 degrees Celsius to determine their mechanical characteristics. [Oleiwi and Ahmed 2016], By varying the quantity of Jute layers and the fiber angle (45° & 90°), the tensile and buckling features of composites reinforced with Jute fiber were examined. The findings exhibited that tensile strength and young modulus were improved by growing the number of Jute strengthening layers in the (0°/90o) direction of fibers.

This study aims to compare hybrids (natural + glass) and (natural + carbon) and examine the effects of creep strain and creep rate on a prosthetic socket for a different laminated. When materials are subjected to prolonged stress, creep should be considered.

EXPERIMENTAL PART

The materials, tools, and preparatory procedures used in the production of sockets that may have advantageous mechanical qualities are covered in this section.

Materials Used

Polyester (produced by B-CHEM corporation), jute fiber, carbon textile (produced by Ottobock corporation), glass fiber (produced by Ottobock corporation), hemp and monofilament fibers from Changzhou Doris Textile Co., Ltd., and Perlon stockinet (item

(623T5) produced by Ottobock corporation are used to test the below-knee socket for this investigation. Other materials required to produce prosthetic sockets include Jepson for casting, hardening powder, and polyvinyl alcohol (PVA) bags.

The natural fibers were immersed in a 5% NaOH substance for approximately 2 hr. at ambient temperature. To improve their longevity and affinity for the matrix, they were carefully cleaned under running water after the alkalization.

Equipment Utilized

A rectangular mold of Jepson measuring 25*20*10 cm3, a vacuum arrangement with a pump and stances to hold the pipes, a mechanical workspace with various gears for CNC cutting and forming, and a universal instrument machine test (testometric) device are the tools needed for this work.

Manufacturing the Composite Materials

Using the vacuum molding process, composite specimens were created by the lamination configuration listed in Table 1. The layers are assembled using a vacuum to ensure that there is no air between the layers. The positive mold was coated with PVA at room temperature, and the pressure controllers were released to 40 kPa. Figure 2 illustrates the application of reinforcement layers made of Perlon, jute, and carbon stockinets according to the lay-up provided in Table 1. A layer of PVA bag was put over the composite layers, and the end of the bag was secured with string. To create a cubic composite material, a combination of polyester and hardening powder blended to a customary (2 percent of the polymer) ratio is inserted into the layers and dispersed uniformly, as seen in Figure 1. They are then smeared for 10 minutes and allowed to steady. The composites were cooled and then sliced to create production specimens for testing. This procedure was carried out again for every lamination. Since the prosthetic socket is made up of various stacking patterns that do not consider direction, these samples were regarded as quasi-isotropic materials.

SPECIMEN PREPARATION AND TESTING

For creep testing, the samples are cut utilizing a CNC appliance.

Creep Test

The laminated composite specimens were subjected to a load of 15 N during the tensile creep test, and they were then allowed to remain at temperature (25 ^{o}C) for 168 hr. till the tensile creep obtained distinguishable values, enabling the plotting of the creep curve. For composite specimens, the creep rate can be measured using the tensile creep curve, which illustrates the connection between strain and time. The creep system used in this work is a type (Gunt machine), as shown in Figure 3, [Annual Book 2001].

RESULTS AND DISCUSSION

The tensile creep performance of laminated composite samples reinforced with only natural textiles is displayed in Figures 4, 5, and 6. It was observed that viscoelastic deformation represents the secondary (or steady-state) zone, while elastic deformation of materials represents the primary region.

Tensile creep experiments were conducted in this work at room temperature Above at (50 ^{o}C) and a fixed stress level (15 N). The tertiary area or third stage of the creep curve is not visible in all laminated composite specimens due to the presence of reinforcing components (Jute, hemp, monofilament fiber layers, or hybrid). [Mallick P. K. 2007].

As demonstrated in Figures 4,5 and 6, these curves showed that creep strain is lower in specimens with three layers of natural fibers (3 J, 3M, and 3H) than in specimens with two layers of natural fibers (2J, 2M, and 2H), and it is lower in specimens with one layer of jute fibers (1J, 1M, and 1H). This is because the expanded number of reinforcing layers decreased the resin Polyester extension concerning the applied load. Creep curves show how the kind and quantity of fiber layers affect the creep strains of laminated composite specimens.

The three-layered natural fiber-reinforced laminates with the best creep performance were then reinforced with glass and carbon fiber, and their behavior was compared and examined as illustrated in the figures. (7, 8, and 9).

Because it plays a crucial function in limiting the bonds between the molecular chains of polyester resin in tests and preventing extension, the usage of hybrid (natural + carbon) fibers resulted in a decreased creep strain with constant natural fiber, as seen in the figures. [Bledzki, and Faruk 2004].

The primary and secondary stages of the creep curve of groups can be used to determine the strength of materials. In contrast to the laminate reinforced with jute and monofilament fibers, as illustrated in Figure 7, a hybrid (Hemp+Cement) showed the lowest creep strain values when applied. Due to the superior creep resistance of carbon fiber and the robust creep resistance of the hybrid (natural+carbon); it was observed that the hybrid (hemp+carbon) has less deflection than the high-deflection hybrid (hemp+glass). However, because jute fiber has a lower creep resistance than carbon, the composites made of jute fiber (Jute+Carbon) have weak creep resistance. When exposed to tensile creep stress, jute fibers become weaker. This is because jute fibers naturally have an uneven structure that is linked to flaws.

Figure 10 displays the creep rate of laminating specimens for hemp, jute, hybrid, and monofilament. As the number of layers rises, the creep rate lowers. There are fewer specimens of carbon-containing hemp hybrid fibers than glass fibers or natural fibers alone.

Of the fifteen groups, Group (1J) had the highest, which could be explained by the fiber's inherent low creep resistance. [Vazquez and Plackett 2004].

CONCLUSIONS

Since materials tend to distort when subjected to prolonged tension, creep should be considered. The following are the study's main conclusions:

- Thermal loading causes creep in materials, which can lead to failure-causing damage.
- As the number of fiber layers rose, both creep strain and creep rates dropped.
- Using carbon plus natural fiber in place of glass fiber resulted in further reductions in both creep strain and creep rate.
- Hemp and carbon have a lot of potential for usage as prosthetic socket materials. Because carbon is lightweight, durable, strong, and easy to manufacture, its use in prosthetic sockets will boost production.

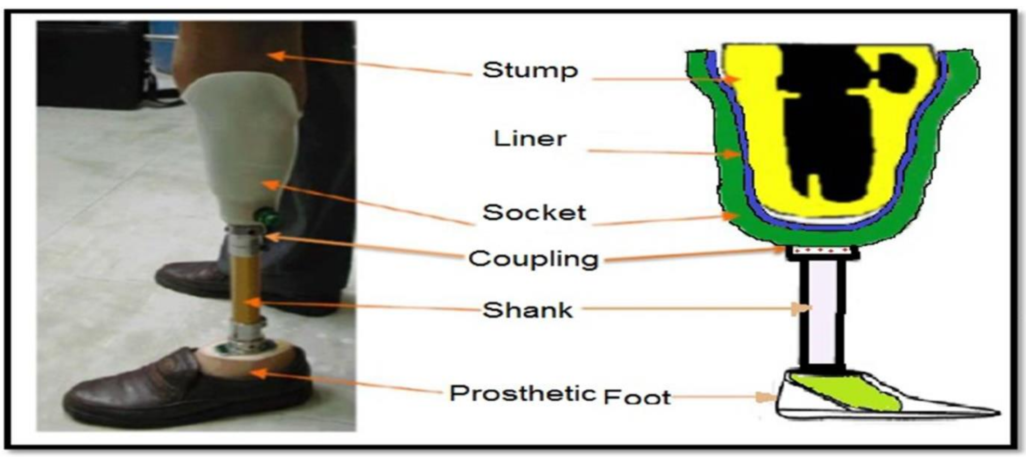

Fig. 1. The main components of the prosthesis [3].

Fig. 2. Procedure of making the samples.

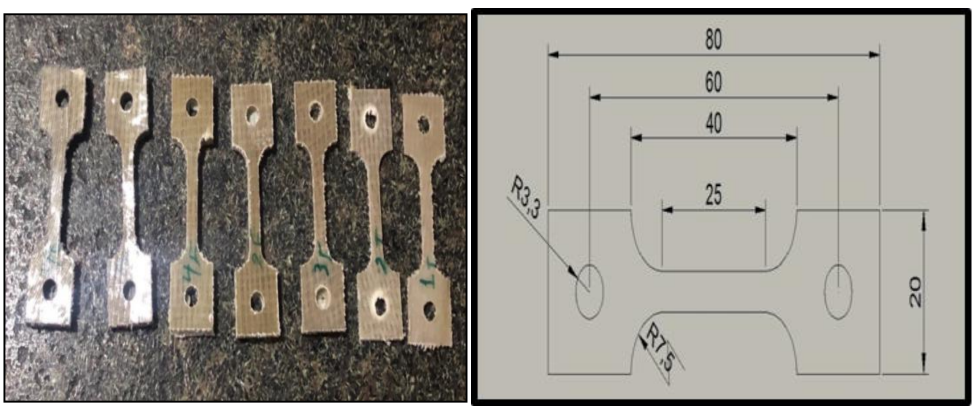

Fig. 3. (a) Samples before a test, (b) The dimension of specimens.

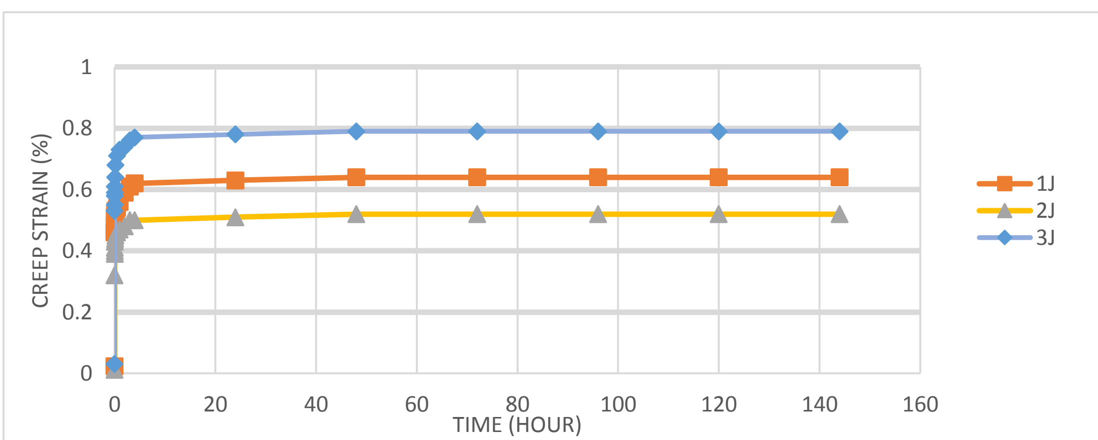

Fig. 4. Creep strain for Jute fibers with layers one, two, and three in laminated composite specimens.

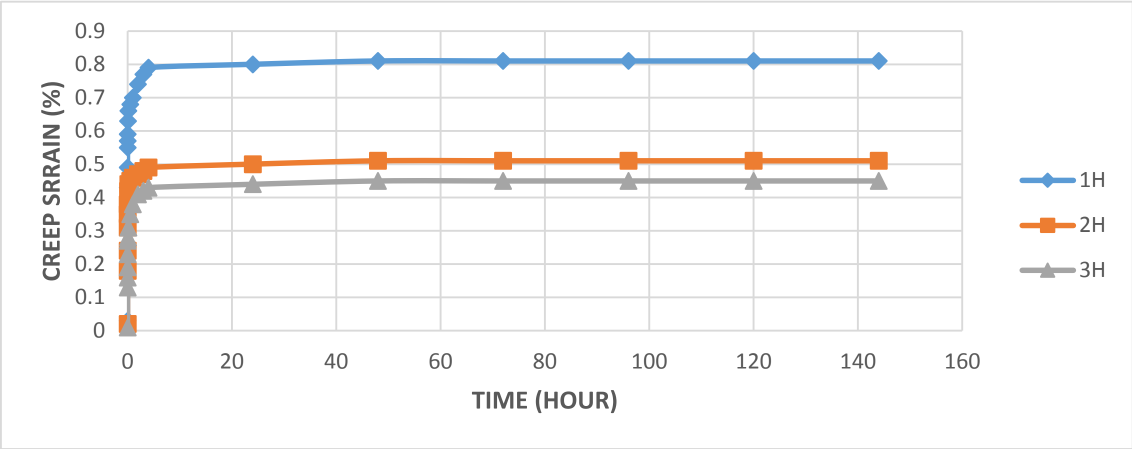

Fig. 5. Creep strain for Hemp fibers with layers one, two, and three in laminated composite specimens

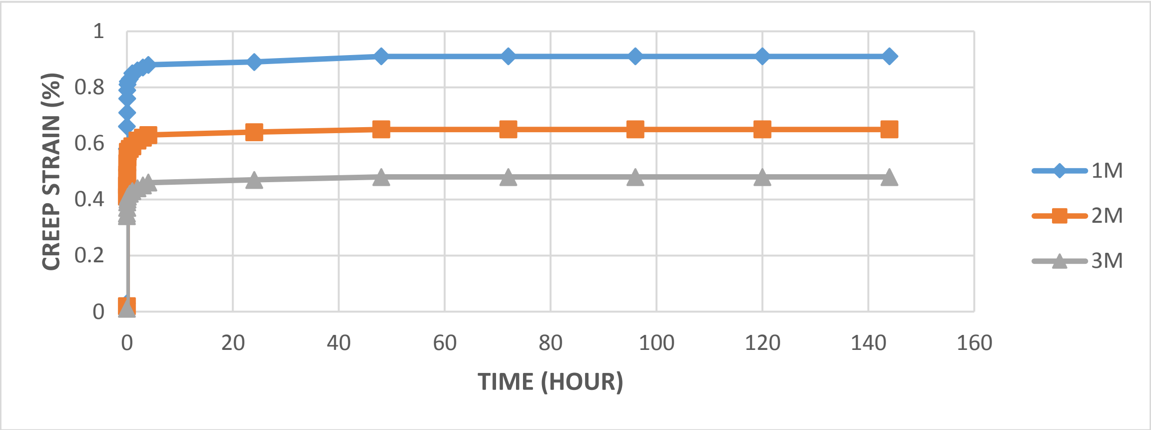

Fig. 6. Creep strain for monofilament fibers with layers one, two, and three in laminated composite specimens.

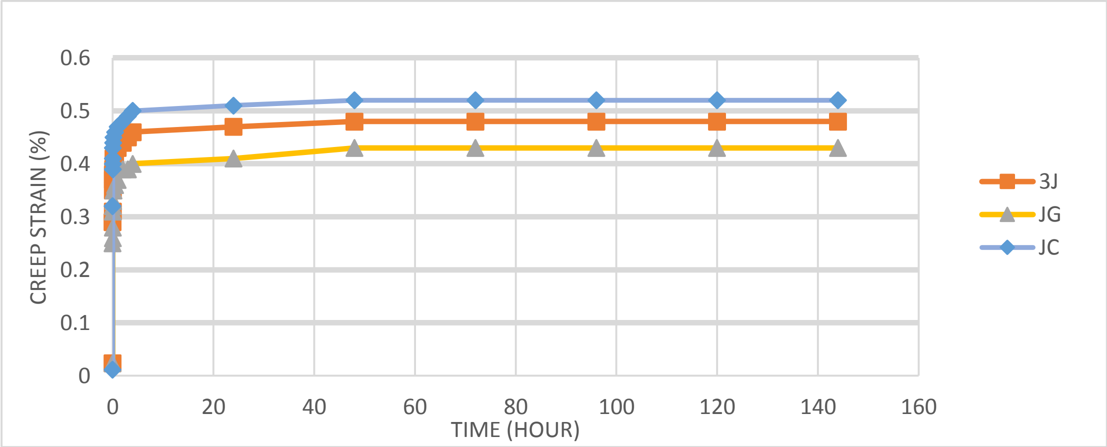

Fig. 7. Creep strain for hybrid fibers (Jute-Carbon-glass) layers in laminated composite specimens.

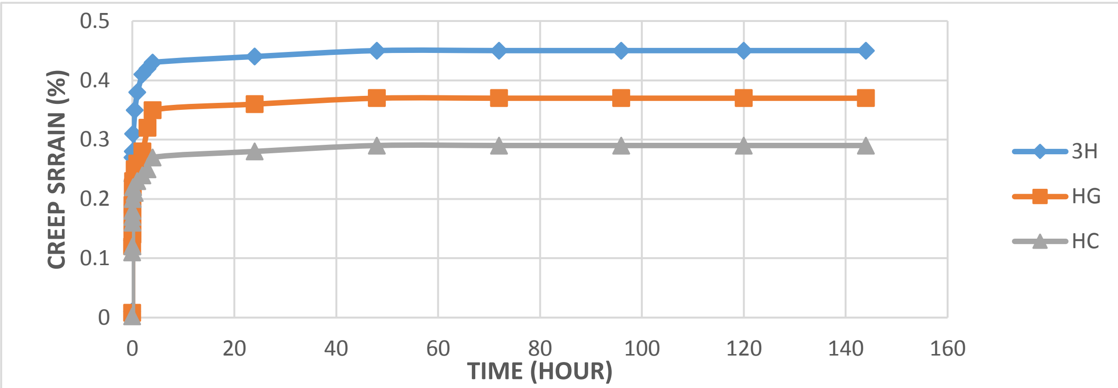

Fig. 8. Creep strain for hybrid fibers (Hemp-Carbon-glass) layers in laminated composite specimens.

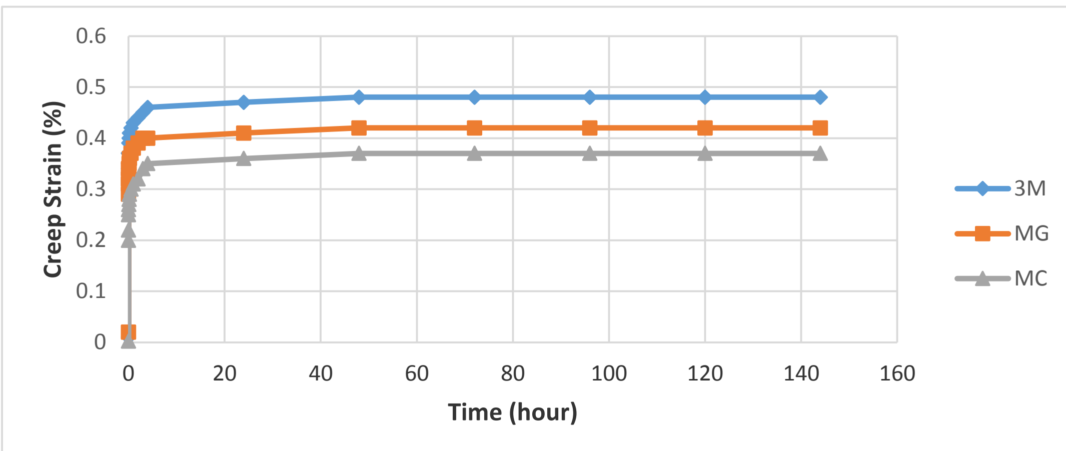

Fig. 9. Creep strain for hybrid fibers (Monofilament-Carbon-glass) layers in laminated composite specimens.

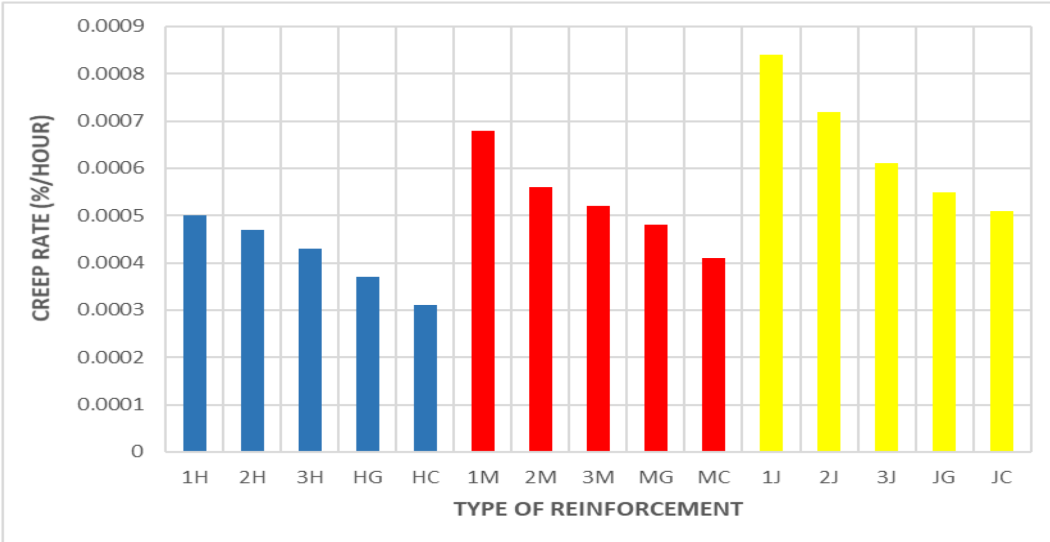

Fig. 10. Creep rate for laminated composite specimens with hybrid fibers layers as function with type of reinforcements.

Table 1. Lay-up Groups

No. of Lamination	Lamination lay-up	Name	Lamination layups
Lamination 1	4 perlon+1 monofilament	1M	(2P +1M+2P)
Lamination 2	4perlon+ 2 monofilament	2M	(2P +2M+2P)
Lamination 3	4perlon+3 monofilament	3M	(2P +3M+2P) layers
Lamination 4	4perlon+3 monofilament+2 Carbon	MC	(2P+1M+1C+1M+1C+1M+2P)
Lamination 5	4perlon+3 monofilament+2 Fiber Glass	MG	(2P+1M+1G+1M+1G+1M+2P)
Lamination 6	4perlon+1hemp	1H	(2P +1H+2P)
Lamination 7	4perlon+2 hemp	2H	(2P +2H+2P)
Lamination 8	4perlon+3hemp	3H	(2P +3H+2P)
Lamination 9	4perlon+3 hemp+2 Carbon	4H	(2P+1H+1C+1H+1C+1H+2P)

Lamination 10	4perlon+3hemp+2 Fiber Glass	5H	(2P+1H+1G+1H+1G+1H+2P)
Lamination 11	4perlon+1 jute	1J	(2P +1J+2P)
Lamination 12	4perlon+2 jute	2J	(2P +1J+2P)
Lamination 13	4perlon+3 jute	3J	(2P +1J+2P)
Lamination 14	4perlon+3 jute+2 Carbon	JC	(2P+1J+1C+1J+1C+1J+2P)
Lamination 15	4perlon+3jute+2 Fiber Glass	JG	(2P+1J+1G+1J+1G+1J+2P)

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